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(54) Bank note identification

(57) Apparatus for identifying the denomination of a bank note comprises a sensor 14 which senses light reflected from an incremental area 16 of a bank note 10 to produce an output which is passed to a storage 24 at intervals. When sufficient sample outputs have been stored in the storage 24 a control 28 causes each sample to be compared in a comparator 30 with a number of previous samples taken in a pre-selected sequence so as to produce a multi-bit correlation number. Each correlation number thus formed is then compared with reference multi-bit numbers derived from scanning a corresponding section of a number of notes of the different denominations to be identified. If the multi-bit number derived from the scanning is the same as any of the reference multi-bit numbers, a correlation count for that particular denomination is incremented. This process is repeated for the whole area of the note and, on completion, the correlation counts for the different denominations are compared. Provided the ratio of the largest correlation count to the next highest correlation count is 1.28 or greater and the largest correlation count is at least 28, the note is identified, as shown by an indicator 36.

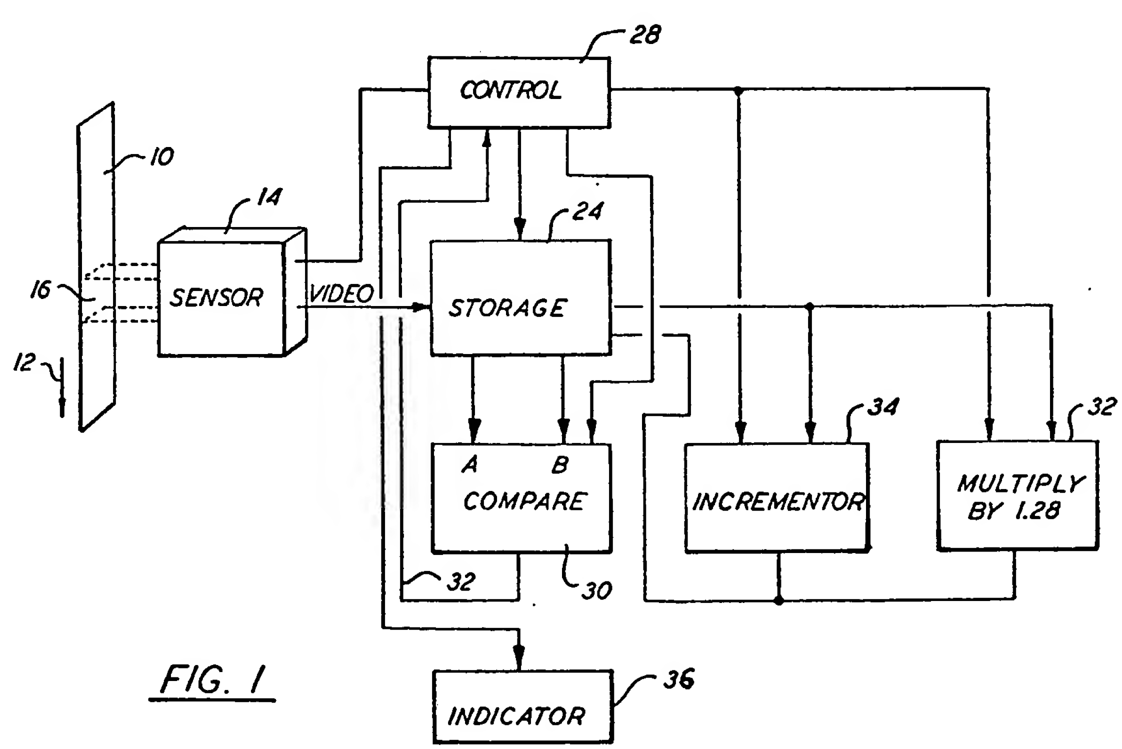

FIG. 1

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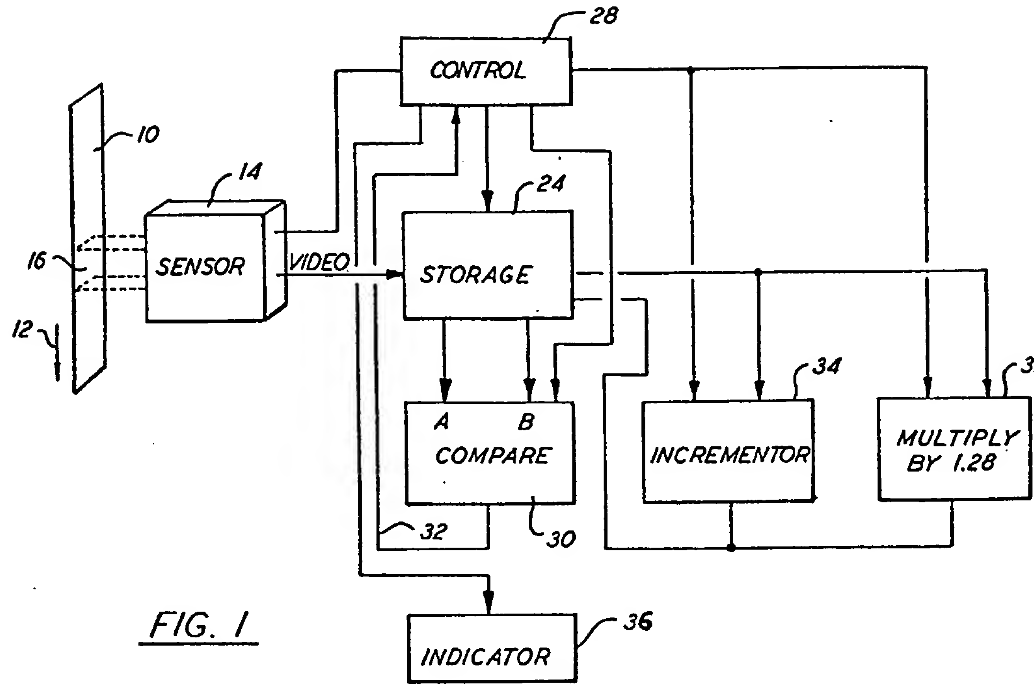

28
CONTROL
10
14
24
16
SENSOR
VIDEO
STORAGE
12
34
32
A
B
COMPARE
INCREMENTOR
MULTIPLY
BY 1.28
32
30
36
INDICATOR

FIG. 1

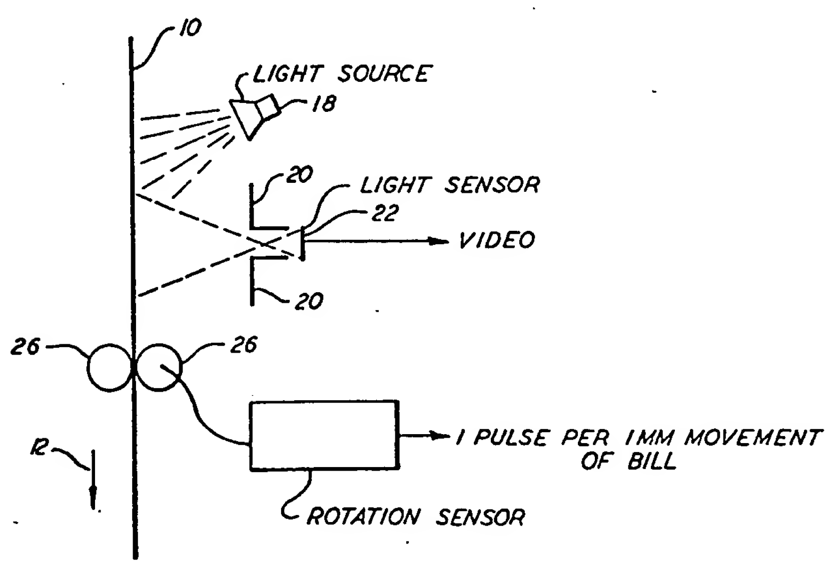

10
LIGHT SOURCE
18
20
LIGHT SENSOR
22
VIDEO
20
26
26
1 PULSE PER 1MM MOVEMENT
OF BILL
12
ROTATION SENSOR

FIG. 1a

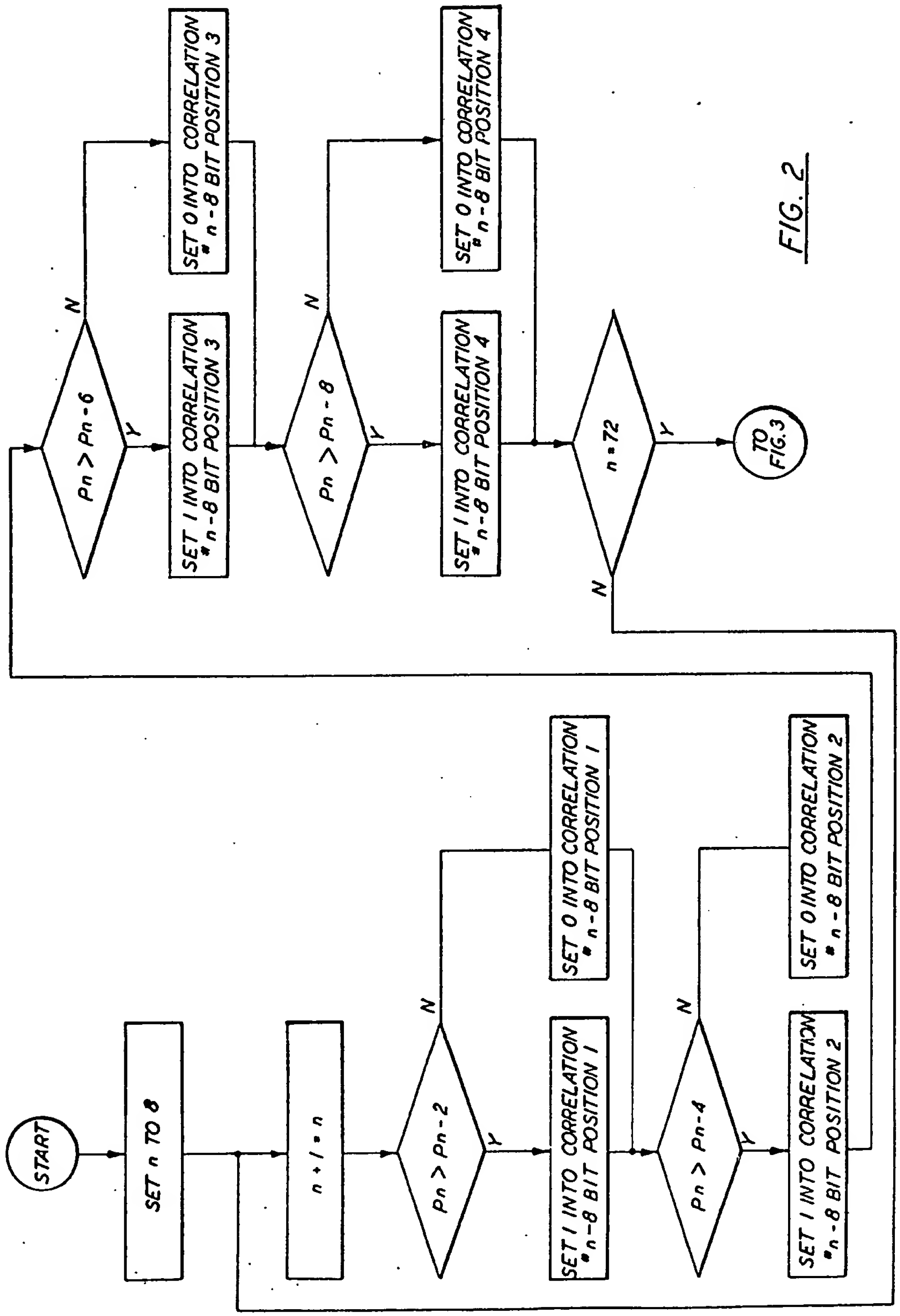

START
SET n TO 8
n + 1 = n
Pn > Pn - 2
Y
N
SET 1 INTO CORRELATION #n-8 BIT POSITION 1
SET 0 INTO CORRELATION #n-8 BIT POSITION 1
Pn > Pn-4
Y
N
SET 1 INTO CORRELATION #n-8 BIT POSITION 2
SET 0 INTO CORRELATION #n-8 BIT POSITION 2
Pn > Pn-6
Y
N
SET 1 INTO CORRELATION #n-8 BIT POSITION 3
SET 0 INTO CORRELATION #n-8 BIT POSITION 3
Pn > Pn - 8
Y
N
SET 1 INTO CORRELATION #n-8 BIT POSITION 4
SET 0 INTO CORRELATION #n-8 BIT POSITION 4
n = 72
Y
N
TO FIG. 3

FIG. 2

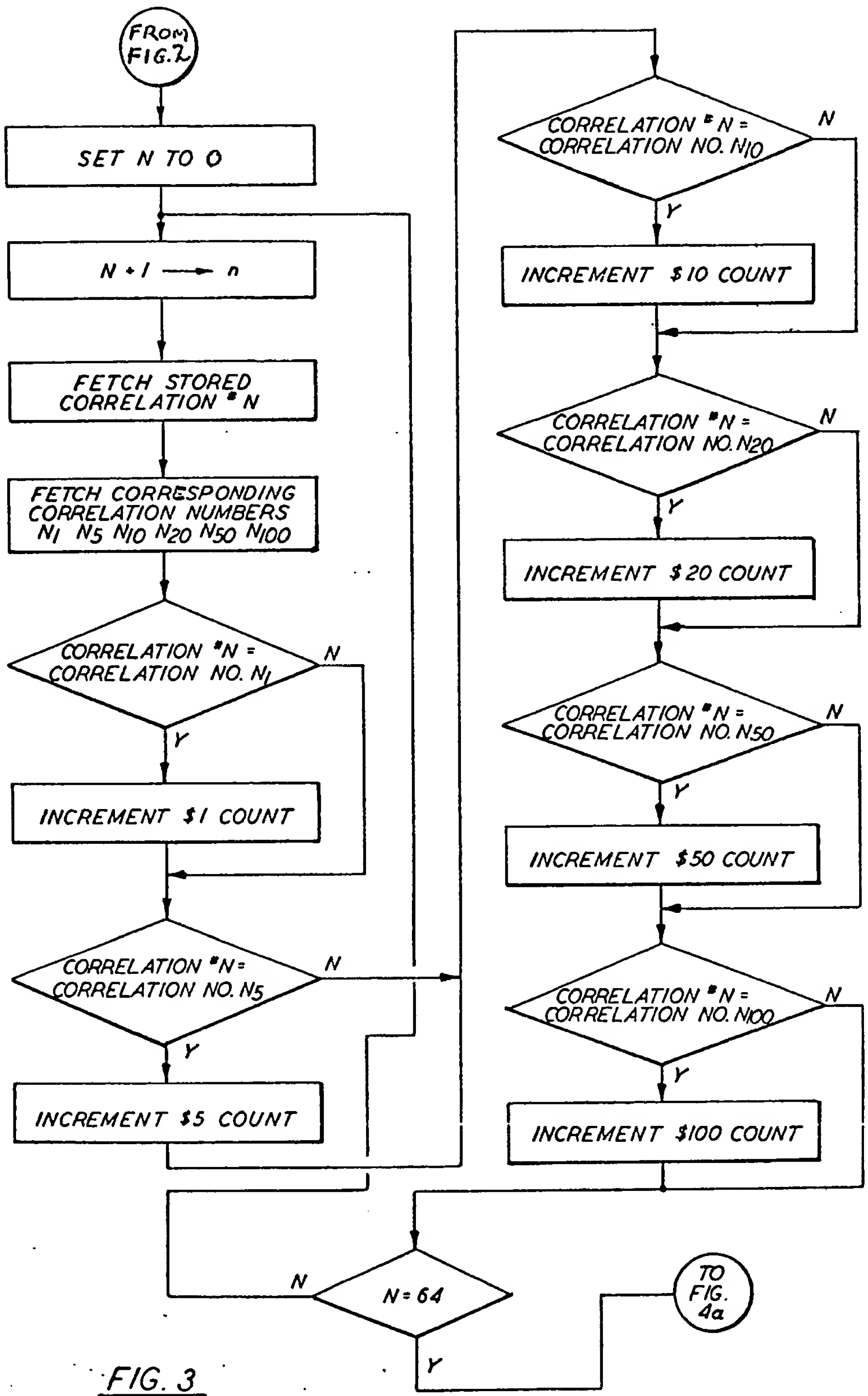

FROM FIG.2
SET N TO O
N + 1 → n
FETCH STORED CORRELATION # N
FETCH CORRESPONDING CORRELATION NUMBERS N1 N5 N10 N20 N50 N100
CORRELATION #N = CORRELATION NO. N1
INCREMENT $1 COUNT
CORRELATION #N = CORRELATION NO. N5
INCREMENT $5 COUNT
CORRELATION #N = CORRELATION NO. N10
INCREMENT $10 COUNT
CORRELATION #N = CORRELATION NO. N20
INCREMENT $20 COUNT
CORRELATION #N = CORRELATION NO. N50
INCREMENT $50 COUNT
CORRELATION #N = CORRELATION NO. N100
INCREMENT $100 COUNT
N = 64
TO FIG. 4a
Y
N

FIG. 3

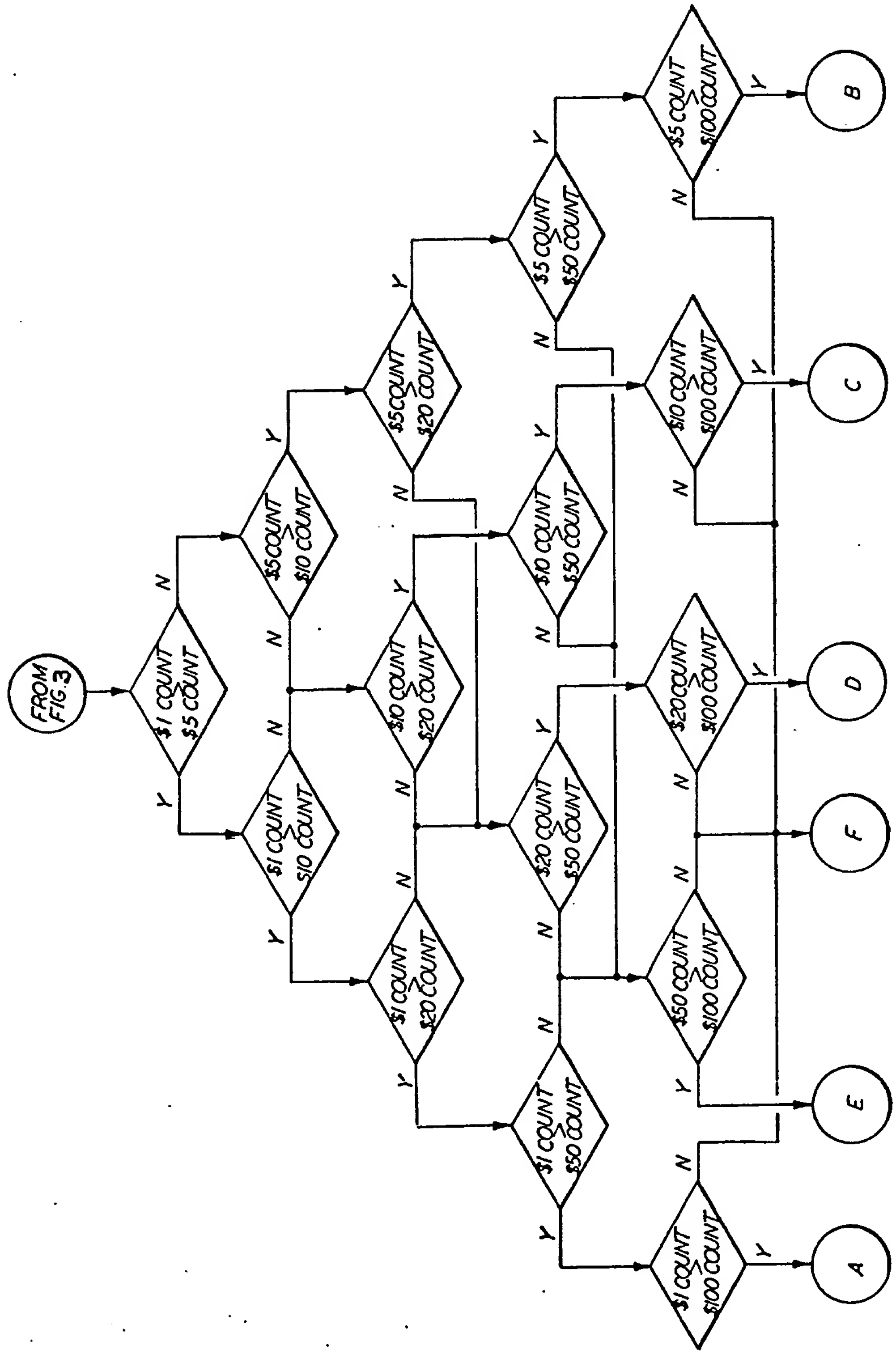

FROM FIG.3
$1 COUNT > $5 COUNT
$5 COUNT > $10 COUNT
$1 COUNT > $10 COUNT
$5 COUNT > $20 COUNT
$10 COUNT > $20 COUNT
$1 COUNT > $20 COUNT
$5 COUNT > $50 COUNT
$10 COUNT > $50 COUNT
$20 COUNT > $50 COUNT
$1 COUNT > $50 COUNT
$5 COUNT > $100 COUNT
$10 COUNT > $100 COUNT
$20 COUNT > $100 COUNT
$50 COUNT > $100 COUNT
$1 COUNT > $100 COUNT
Y
N
A
B
C
D
E
F

FIG. 4a

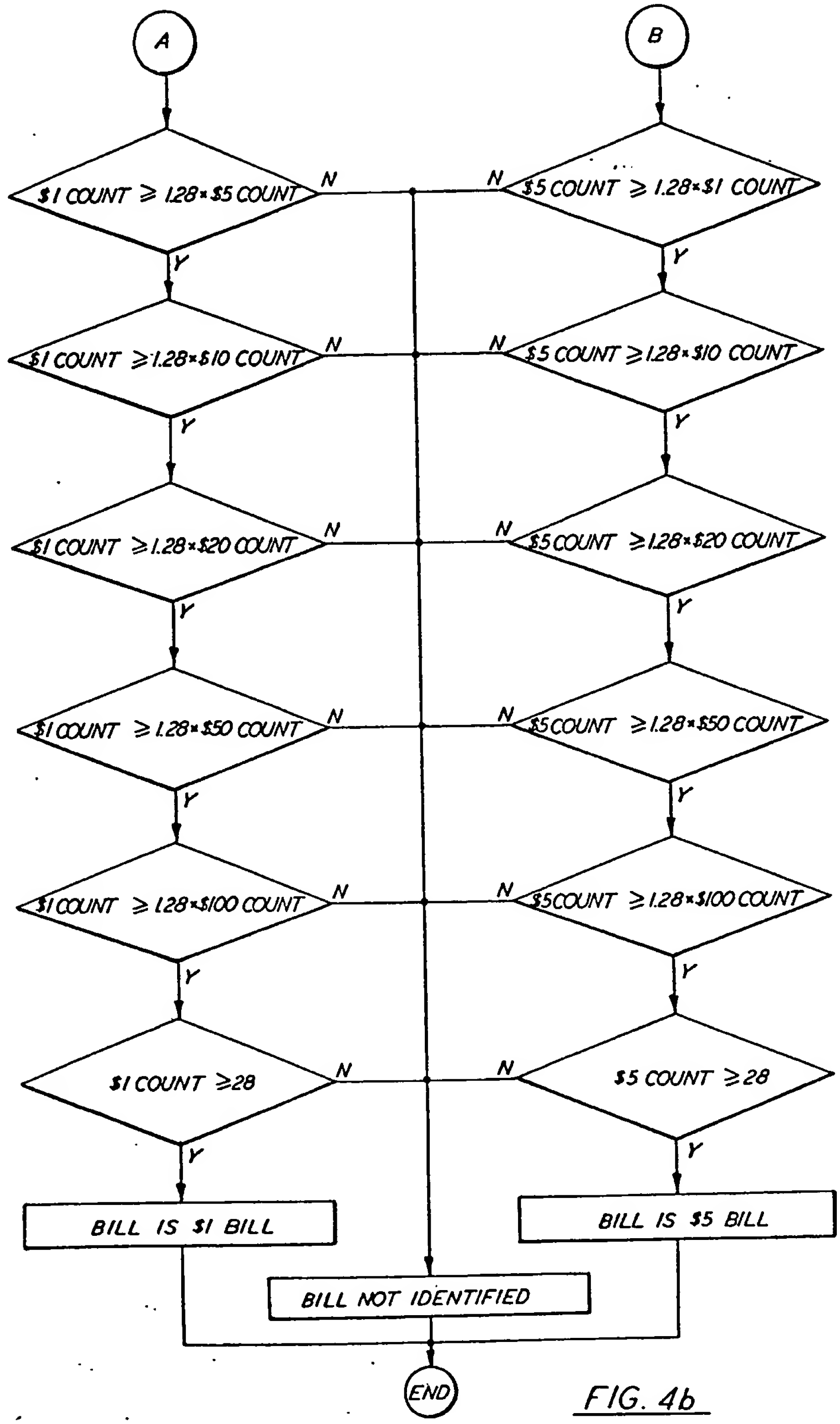

A
B
$1 COUNT ≥ 1.28×$5 COUNT
$5 COUNT ≥ 1.28×$1 COUNT
$1 COUNT ≥ 1.28×$10 COUNT
$5 COUNT ≥ 1.28×$10 COUNT
$1 COUNT ≥ 1.28×$20 COUNT
$5 COUNT ≥ 1.28×$20 COUNT
$1 COUNT ≥ 1.28×$50 COUNT
$5 COUNT ≥ 1.28×$50 COUNT
$1 COUNT ≥ 1.28×$100 COUNT
$5 COUNT ≥ 1.28×$100 COUNT
$1 COUNT ≥ 28
$5 COUNT ≥ 28
N
Y
BILL IS $1 BILL
BILL IS $5 BILL
BILL NOT IDENTIFIED
END

FIG. 4b

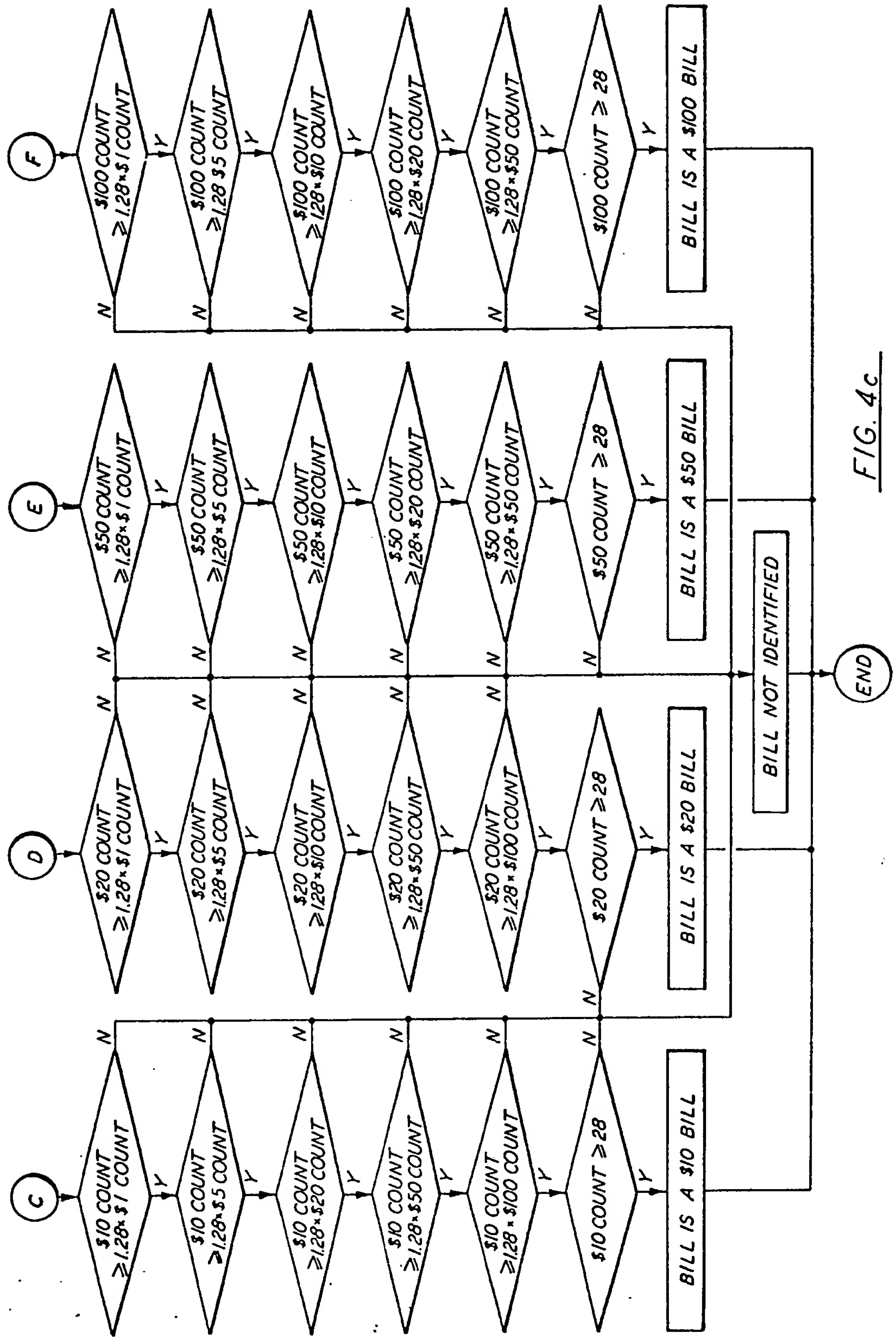

F
$100 COUNT ≥ 1.28×$1 COUNT
$100 COUNT ≥ 1.28 $5 COUNT
$100 COUNT ≥ 1.28×$10 COUNT
$100 COUNT ≥ 1.28×$20 COUNT
$100 COUNT ≥ 1.28×$50 COUNT
$100 COUNT ≥ 28
BILL IS A $100 BILL
E
$50 COUNT ≥ 1.28×$1 COUNT
$50 COUNT ≥ 1.28×$5 COUNT
$50 COUNT ≥ 1.28×$10 COUNT
$50 COUNT ≥ 1.28×$20 COUNT
$50 COUNT ≥ 1.28×$50 COUNT
$50 COUNT ≥ 28
BILL IS A $50 BILL
BILL NOT IDENTIFIED
END
D
$20 COUNT ≥ 1.28×$1 COUNT
$20 COUNT ≥ 1.28×$5 COUNT
$20 COUNT ≥ 1.28×$10 COUNT
$20 COUNT ≥ 1.28×$50 COUNT
$20 COUNT ≥ 1.28×$100 COUNT
$20 COUNT ≥ 28
BILL IS A $20 BILL
C
$10 COUNT ≥ 1.28×$1 COUNT
$10 COUNT ≥ 1.28×$5 COUNT
$10 COUNT ≥ 1.28×$20 COUNT
$10 COUNT ≥ 1.28×$50 COUNT
$10 COUNT ≥ 1.28×$100 COUNT
$10 COUNT ≥ 28
BILL IS A $10 BILL
Y
N

FIG. 4c

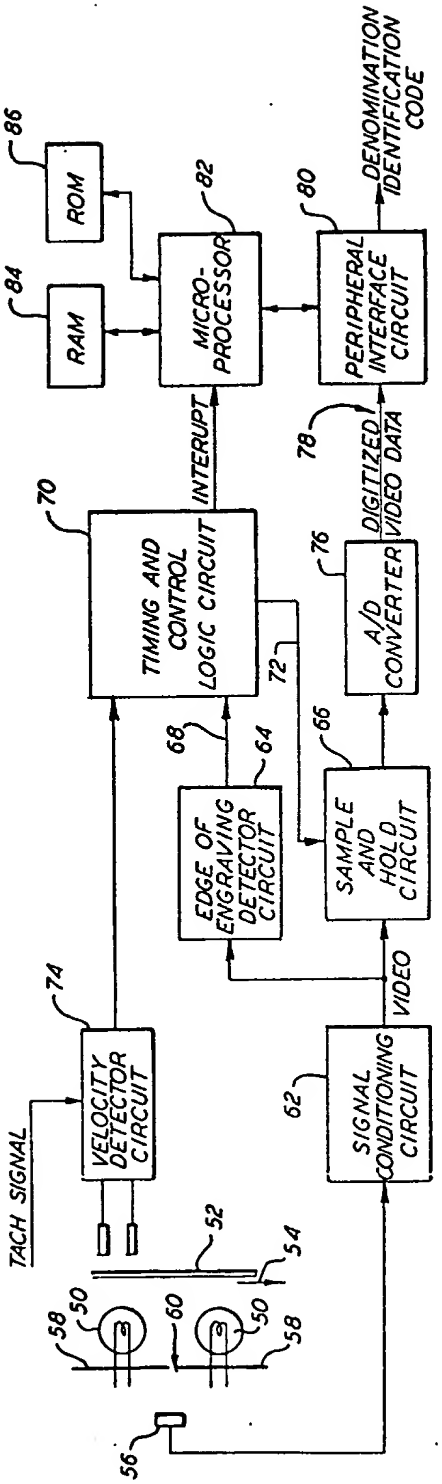


FIG. 5

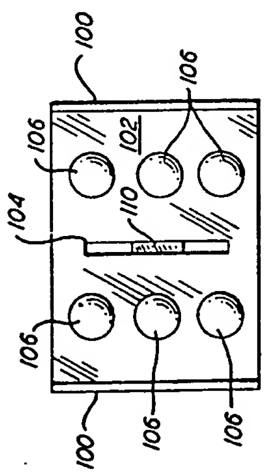


FIG. 6a

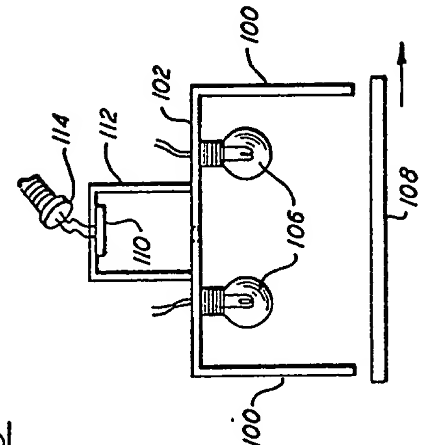


FIG. 6b

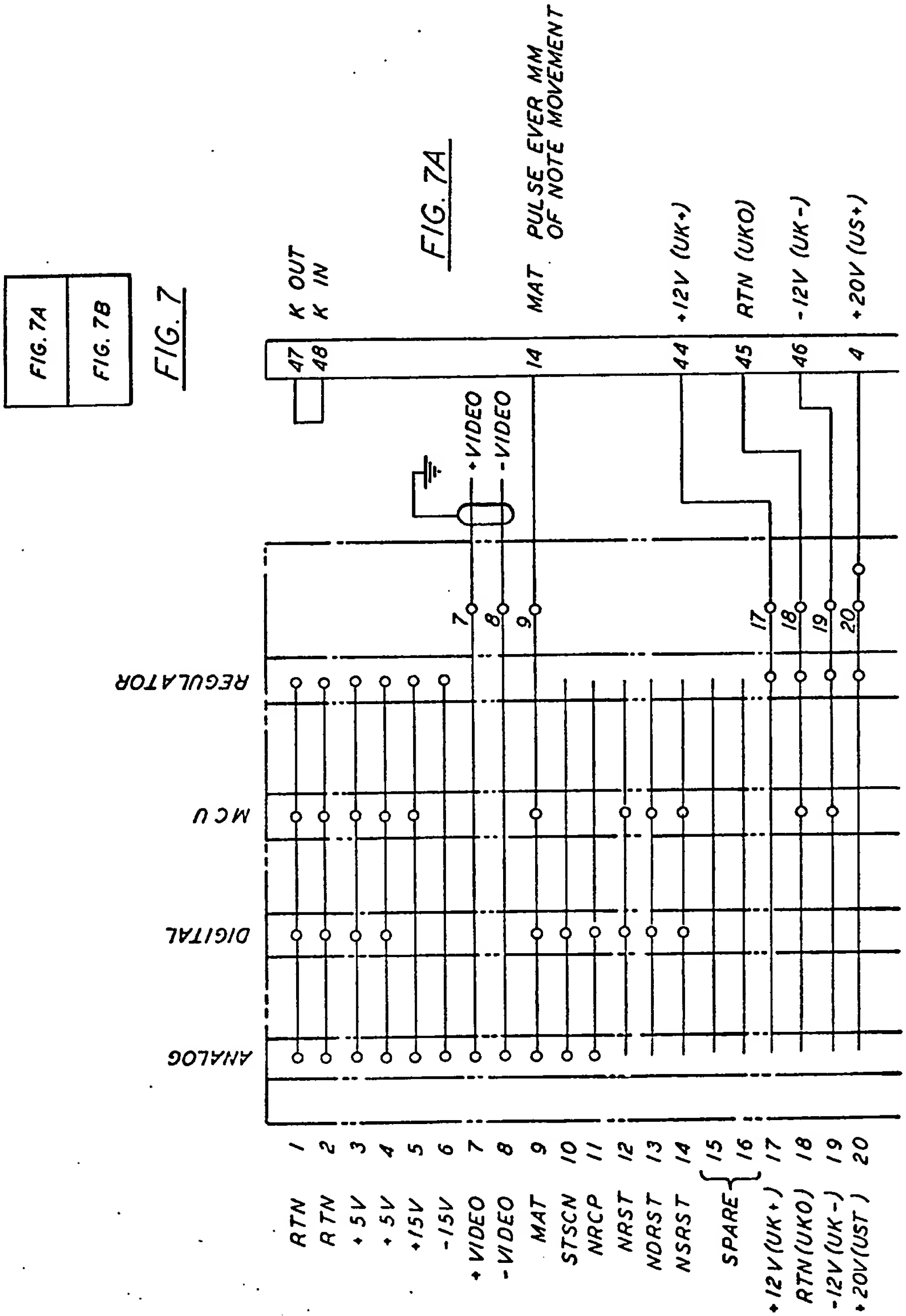


FIG. 7A
FIG. 7B
K OUT
K IN
MAT
PULSE EVER MM OF NOTE MOVEMENT
+12V (UK+)
RTN (UKO)
-12V (UK-)
+20V (US+)
47
48
14
44
45
46
4
+VIDEO
-VIDEO
REGULATOR
MCU
DIGITAL
ANALOG
RTN
RTN
+5V
+5V
+15V
-15V
+VIDEO
-VIDEO
MAT
STSCN
NRCP
NRST
NDRST
NSRST
SPARE
+12V (UK+)
RTN (UKO)
-12V (UK-)
+20V (UST)

FIG. 7

FIG. 7A

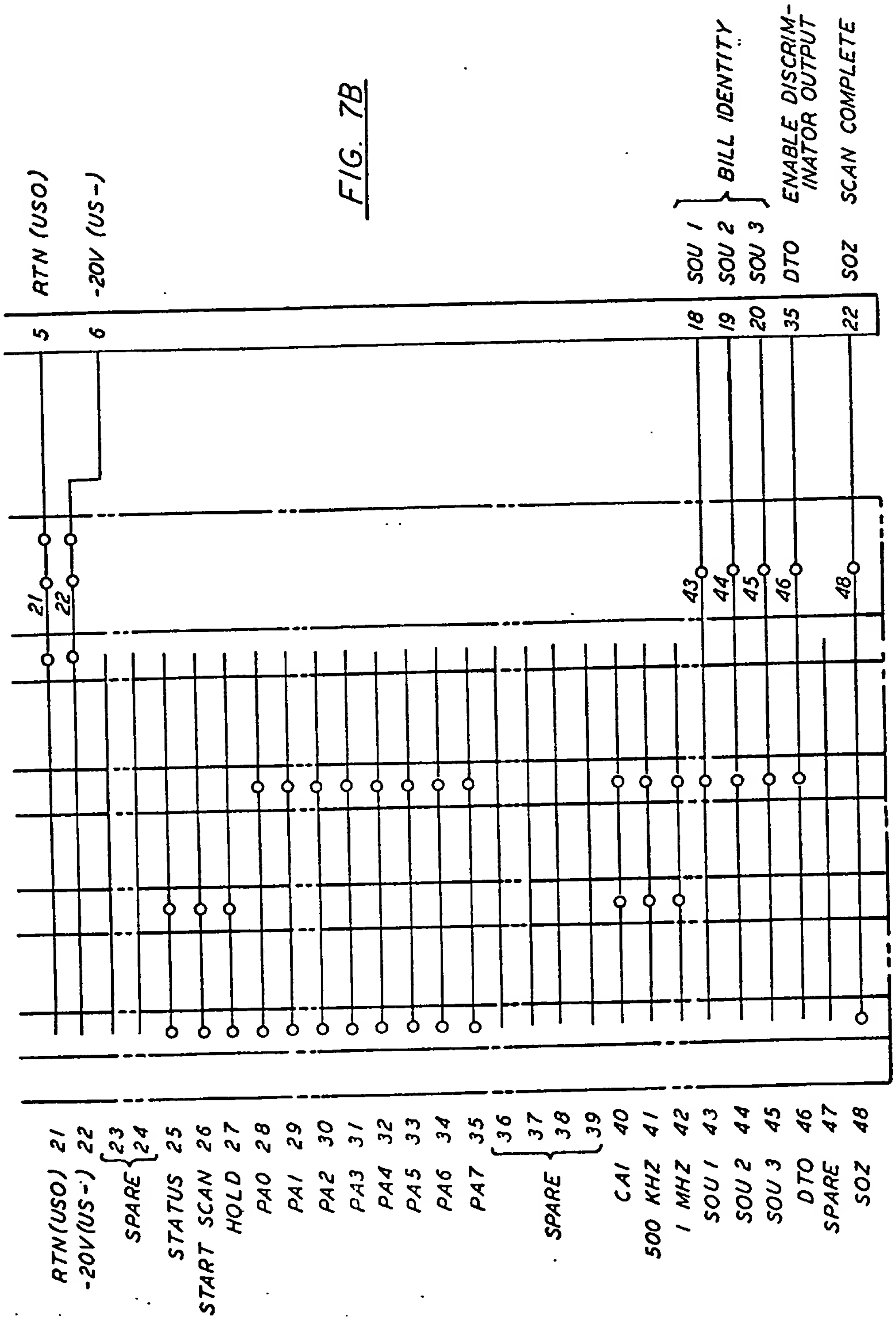
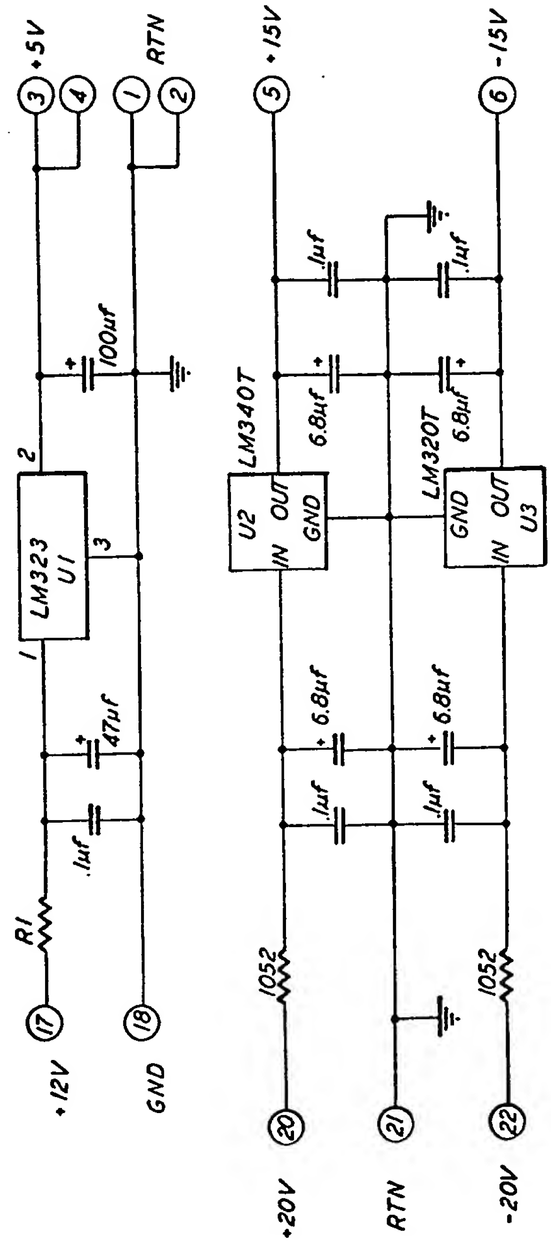

RTN (USO)
-20V (US-)
SOU 1
SOU 2
SOU 3
DTO
SOZ
BILL IDENTITY
ENABLE DISCRIM-INATOR OUTPUT
SCAN COMPLETE
5
6
18
19
20
35
22
21
22
43
44
45
46
48
RTN(USO) 21
-20V(US-) 22
SPARE 23 24
STATUS 25
START SCAN 26
HOLD 27
PA0 28
PA1 29
PA2 30
PA3 31
PA4 32
PA5 33
PA6 34
PA7 35
SPARE 36 37 38 39
CA1 40
500 KHZ 41
1 MHZ 42
SOU 1 43
SOU 2 44
SOU 3 45
DTO 46
SPARE 47
SOZ 48

FIG. 7B



+5V
RTN
+15V
-15V
3
4
1
2
5
6
100uf
.1uf
6.8uf
LM340T
LM320T
LM323
U1
U2
U3
IN
OUT
GND
47uf
R1
1052
17
18
20
21
22
+12V
GND
+20V
RTN
-20V

FIG. 8

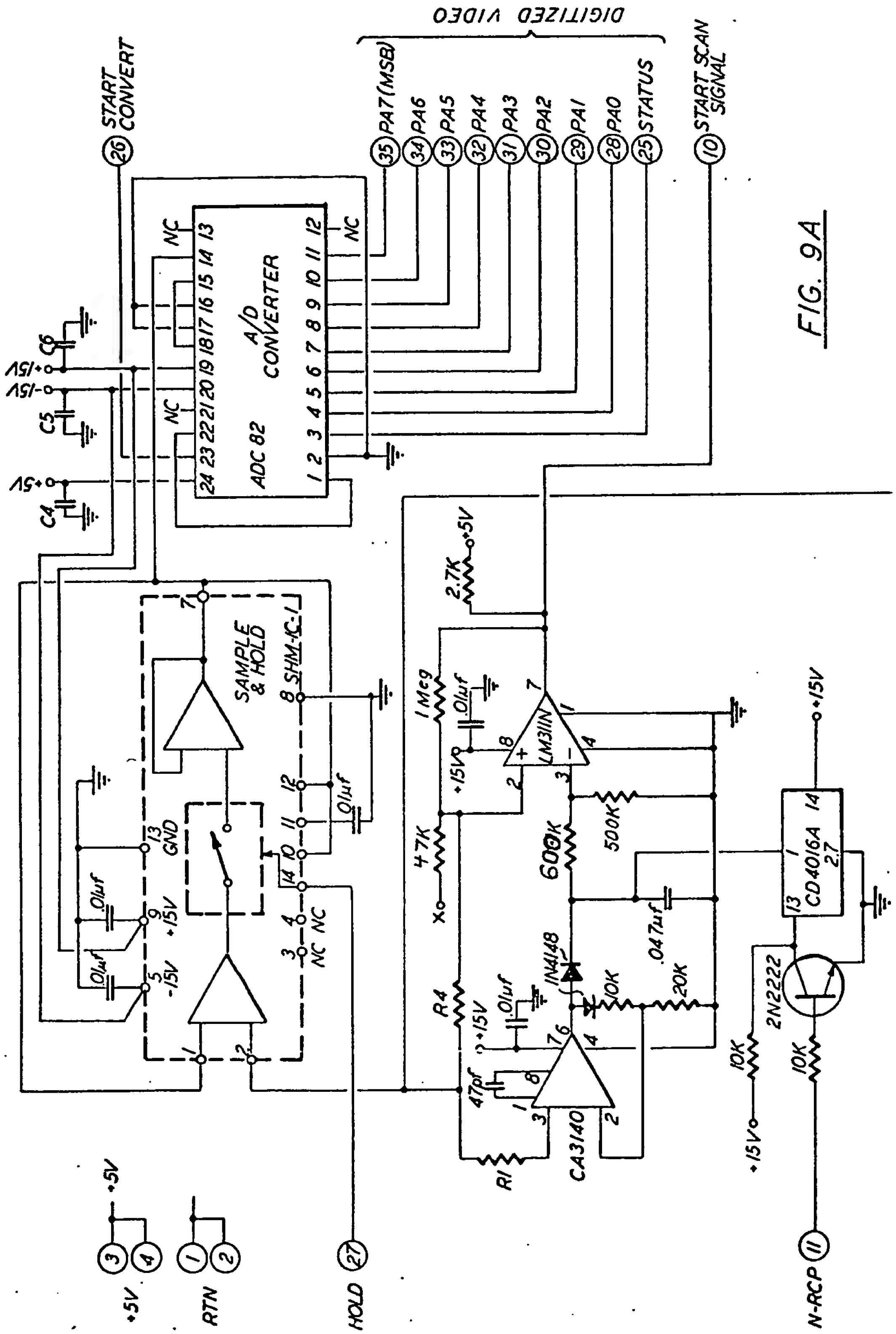

DIGITIZED VIDEO
START CONVERT
PA7 (MSB)
PA6
PA5
PA4
PA3
PA2
PA1
PA0
STATUS
START SCAN SIGNAL
A/D CONVERTER
ADC 82
NC
+15V
-15V
+5V
C4
C5
C6
SAMPLE & HOLD
SHM-IC-1
GND
.01uf
LM311N
CA3140
1N4148
CD4016A
2N2222
1 Meg
2.7K
47K
500K
600K
10K
20K
.047uf
47pf
R1
R4
HOLD
RTN
N-RCP

FIG. 9A

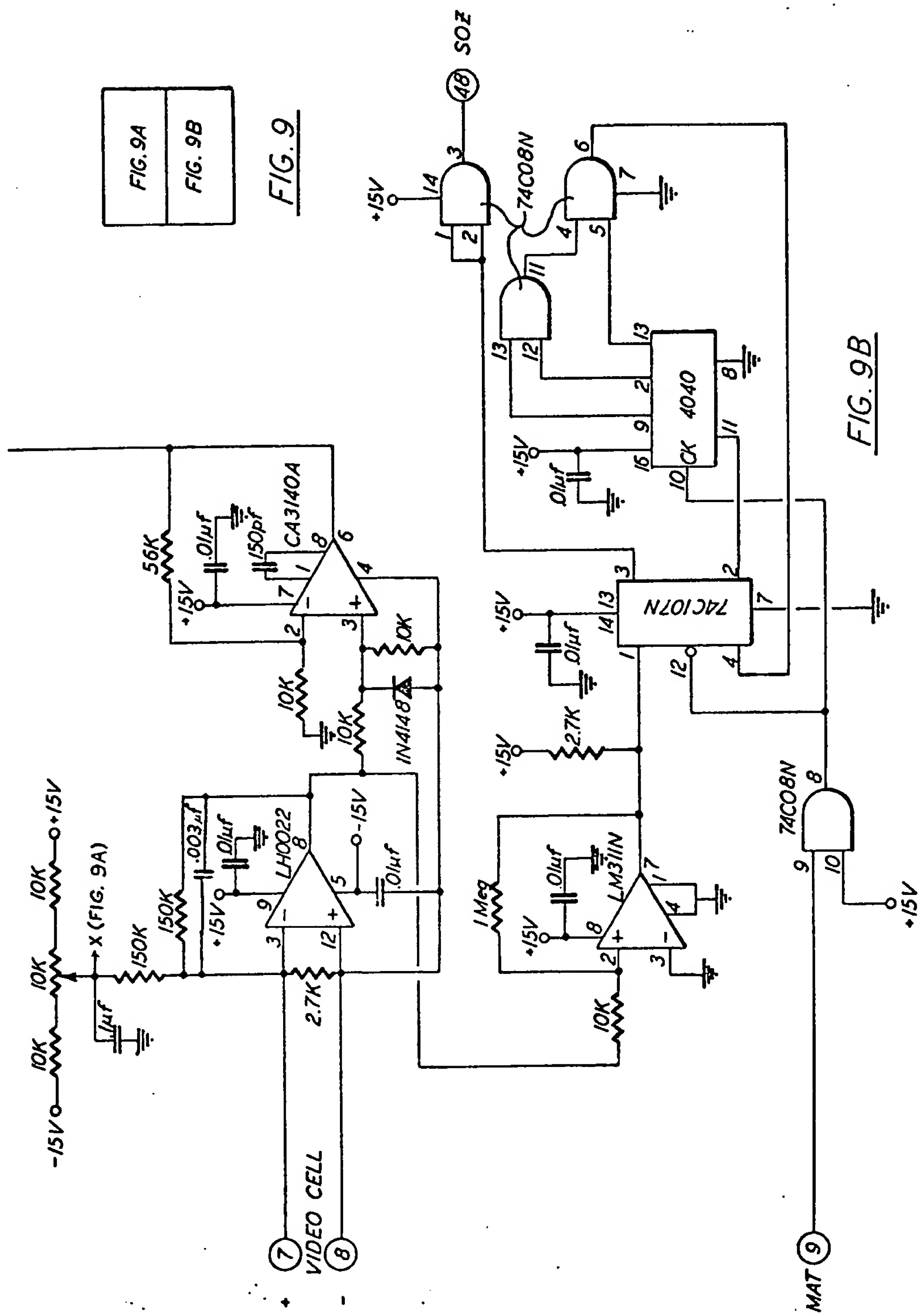


FIG. 9A
FIG. 9B
SOZ
48
+15V
74C08N
74C107N
4040
CK
CA3140A
56K
.01uf
150pf
10K
IN4148
LH0022
.003uf
150K
X (FIG. 9A)
-15V
1uf
2.7K
VIDEO CELL
7
8
LM311N
1 Meg
MAT
9

FIG. 9

FIG. 9B

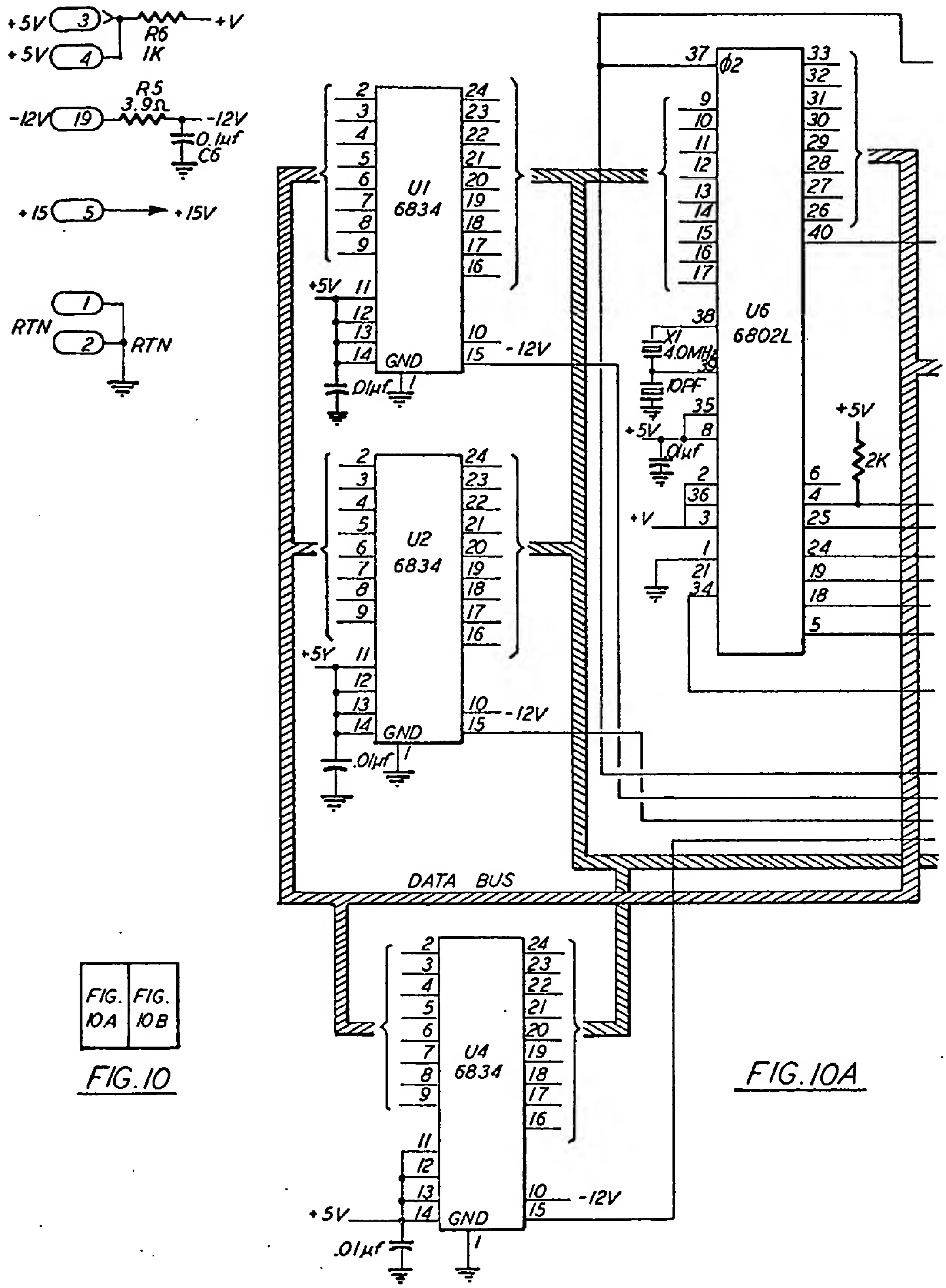


FIG. 10

FIG. 10A

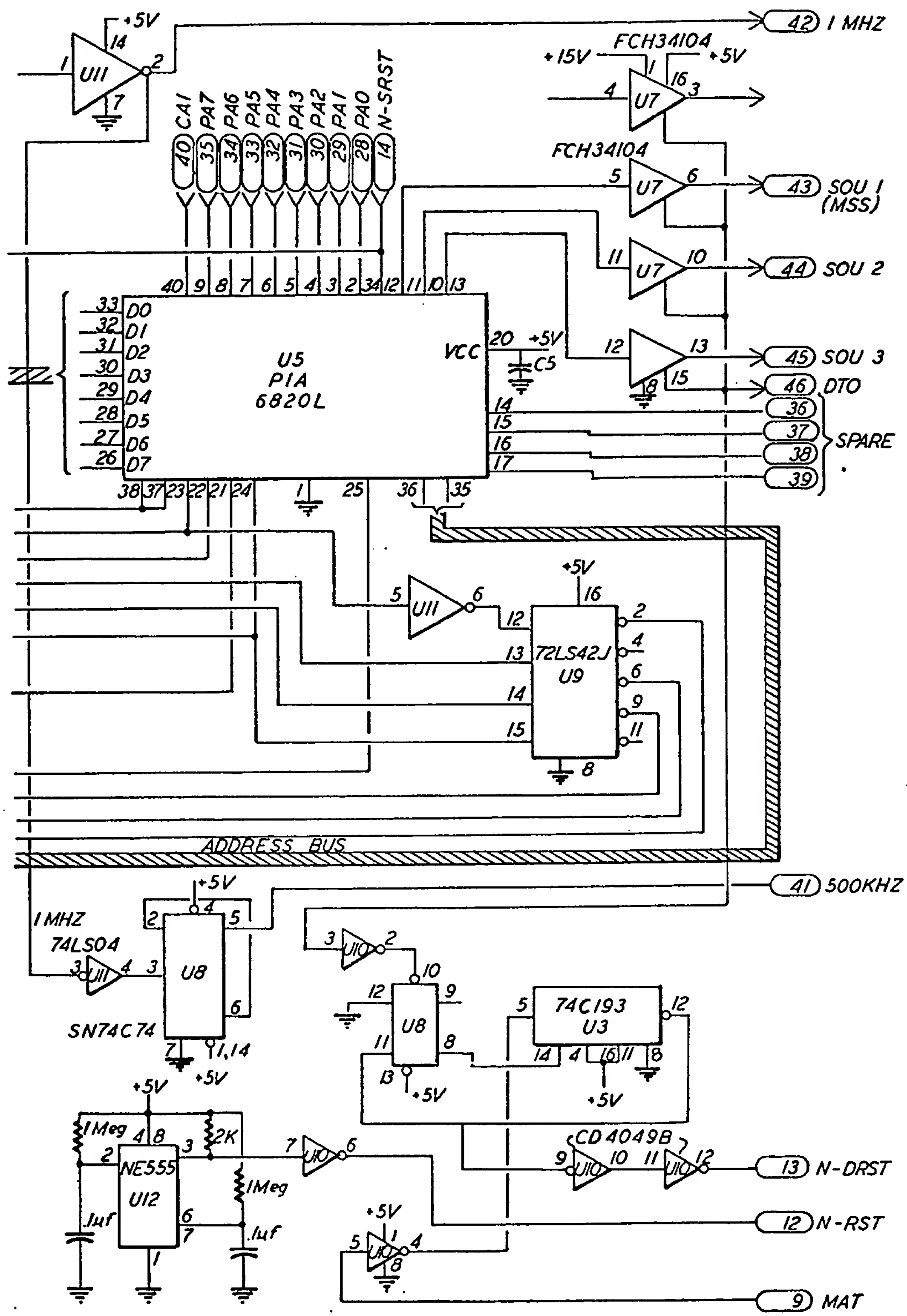
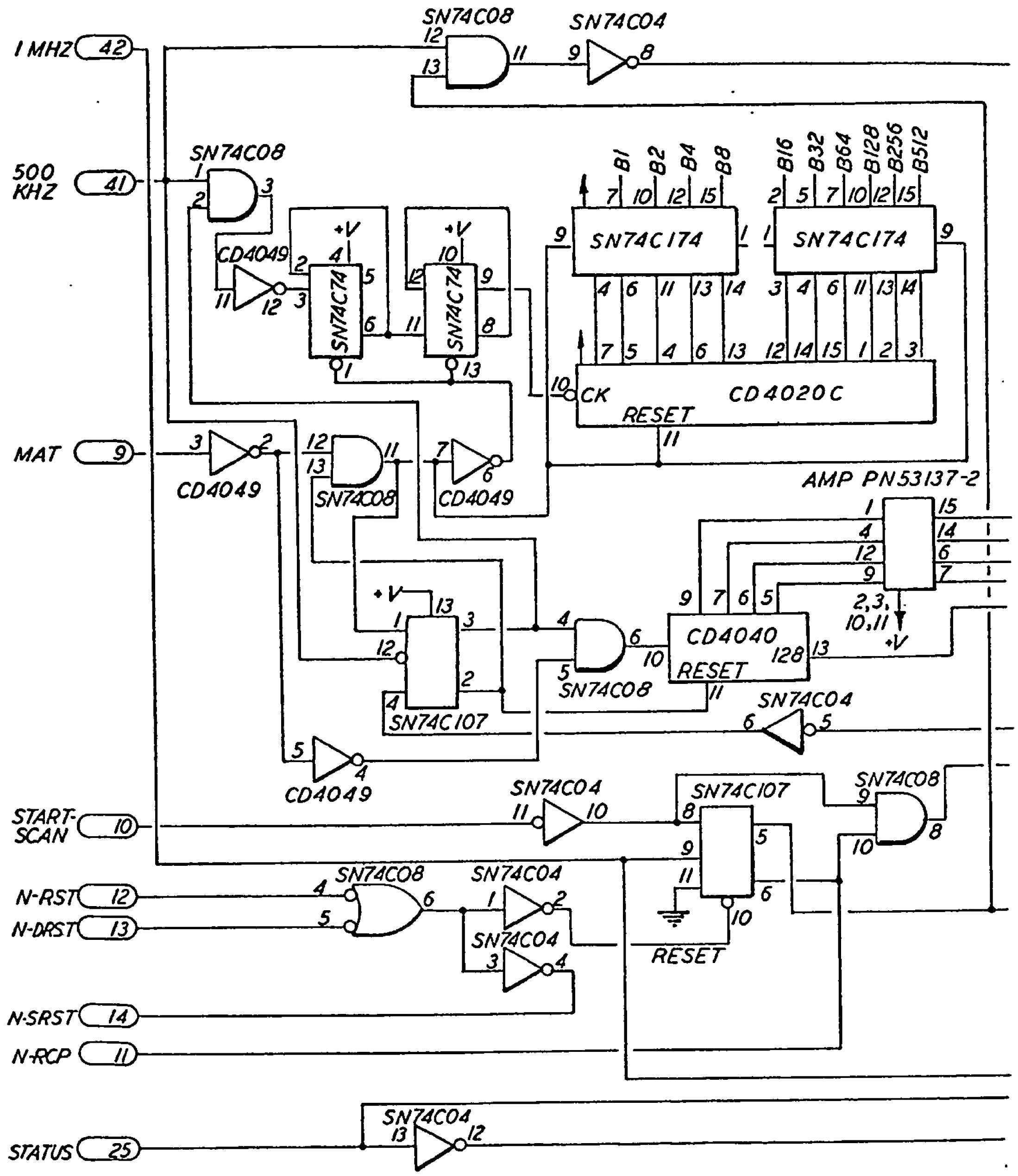

+5V
U11
42 1 MHZ
FCH34104
+15V
+5V
U7
CA1
PA7
PA6
PA5
PA4
PA3
PA2
PA1
PA0
N-SRST
43 SOU 1 (MSS)
44 SOU 2
45 SOU 3
46 DTO
36
37
38
39
SPARE
U5
PIA
6820L
VCC
C5
D0
D1
D2
D3
D4
D5
D6
D7
72LS42J
U9
ADDRESS BUS
41 500KHZ
1 MHZ
74LS04
U8
SN74C74
74C193
U3
NE555
U12
1Meg
2K
1uf
CD4049B
U10
13 N-DRST
12 N-RST
9 MAT

FIG. 10 B



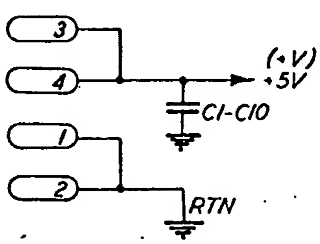


FIG. 11A

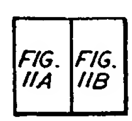


FIG. 11

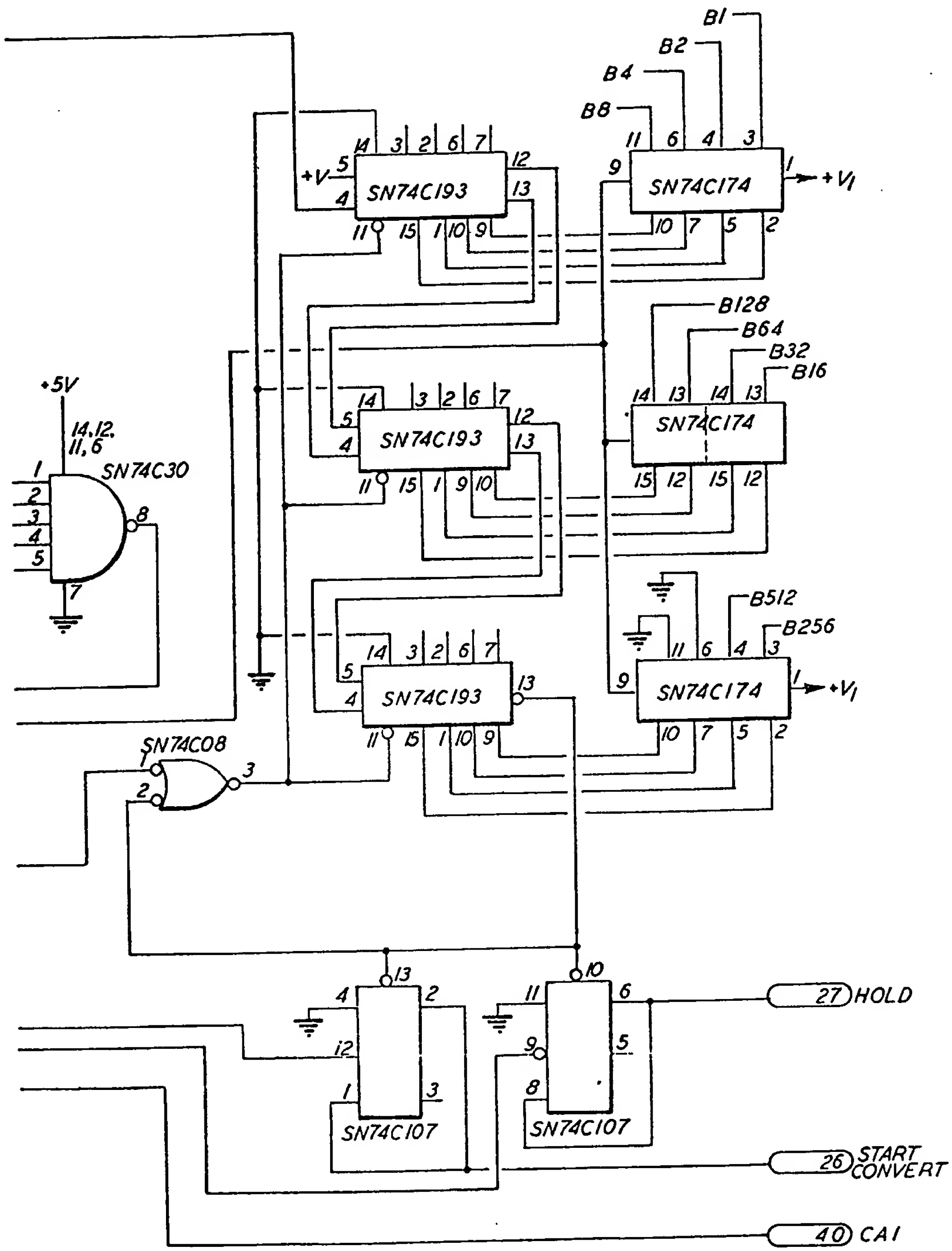

SN74C193
SN74C193
SN74C193
SN74C174
SN74C174
SN74C174
SN74C30
SN74C08
SN74C107
SN74C107
+5V
+V
+V1
B1
B2
B4
B8
B16
B32
B64
B128
B256
B512
27 HOLD
26 START CONVERT
40 CA1

FIG. 11B

SPECIFICATION

Bank note identification

The invention relates generally to automated banking equipment and particularly to an automatic currency discriminator for currency counting machines and the like.

In the field of automated banking, many sophisticated machines have been developed in recent years which are useful in automating many of the heretofore manual operations performed in the banking industry. Of particular concern has been automated equipment for identifying the denomination of currency.

Many of the existing techniques are either excessively complicated, making high speed verification difficult, or they lack the required accuracy for application in the banking industry. Furthermore, those approaches which are complicated also suffer from being rather costly to implement, regardless of operation speed.

It is, therefore, a principal objective of the present invention to provide a currency discriminator particularly useful in high speed automated banking devices such as currency counters.

According to the present invention, the denomination of a bank note or the like is identified by a method in which a source of light is directed onto one surface of the bank note whose denomination is to be determined, the reflectance of light from a number of incremental areas disposed along the length of the bank note is measured, the reflectance of light from each incremental area is compared with the reflectance of light from each of a preselected number of other incremental areas taken in a pre-selected sequence so as to produce a first correlation signal responsive to the comparison for each incremental area and the first correlation signals are compared with respective second reference correlation signals corresponding to each denomination required to be identified so as to determine the denomination of the bank note.

Apparatus for this purpose, in accordance with the invention, comprises means to produce a signal p_n whose magnitude is proportioned to the reflectance of light from an area of a bank note, means to store a representation for the reflectance of light from each of a plurality of different areas on the bank note, means to form a plurality of multi-bit correlation numbers N, where the first bit of each number is a one if $p_n > p_{n-2}$ but otherwise it is a zero, the second bit of each number is a one if $p_n > p_{n-4}$ but otherwise the second bit is zero, the third bit of each number is a one if $p_n > p_{n-6}$ but otherwise the third bit is zero and the fourth bit of each number is a one if $p_n > p_{n-8}$ but otherwise the fourth bit is zero, where p_n is the stored representation for the reflectance of light from a given area, p_{n-2} is the stored representation for the reflectance of light from the second previous given area, p_{n-4} is the stored representation for the reflectance from the fourth previous given area, p_{n-6} is the stored representation for the reflectance from the sixth previous given area and p_{n-8} is the stored representation for the reflectance from the eighth previous given area, means for comparing each said multi-bit correlation number n with a multi-bit number which corresponds to the same four bit number derived from a sample note of each denomination of bank note detected by the apparatus and, on a favourable comparison, for incrementing a denomination count for the corresponding denomination, and means for producing an identity signal correlated to the identified denomination if the denomination count for such denomination is at least equal to 28 and is at least 1.28 times any other denomination count.

The invention will now be described in more detail, with reference to the accompanying drawings, in which:–

Figure 1 is a block diagram of electronic circuitry for a currency discriminator according to the present invention;

Figure 1a shows a sensor of Fig. 1 in diagrammatic form;

Figure 2 shows the manner in which the control circuit of Fig. 1 is operable to cause the remaining circuitry to form a multi-bit correlation number N;

Figure 3 shows the manner in which the control operates the remainder of the equipment so as to determine the largest correlation number N;

Figures 4a, 4b and 4c show how the controls determine whether the largest correlation count is equal to or greater than 1.28 times the next largest correlation count;

Figure 5 is a system block diagram for the preferred form of discriminator;

Figure 6a is a front view of a sensor used in the preferred form of discriminator;

Figure 6b is a plan view corresponding to Fig. 6a;

Figures 7A and 7B are wiring diagrams;

Figure 7 shows how the wiring diagrams of Figs. 7A and 7B fit together;

Figure 8 shows a voltage regulator for the system;

Figures 9A and 9B show an analogue signal processor;

Figure 9 shows how the analogue signal processor of Figs. 9A and 9B fit together;

Figures 10A and 10B show a main processor;

Figure 10 shows how the main processor of Figs. 10A and 10B fit together;
Figures 11A and 11B show a digital signal processor; and
Figure 11 shows how the digital signal processor of Figs. 11A and 11B fit together.

In the diagram of Fig. 1, a bank note 10 is shown as being transported in the direction of the arrow 12 past a bank note sensor 14 which is arranged so that an area on the bank note, indicated at 16, is illuminated and the light reflected therefrom is sensed by the sensor 14. The sensor 14 is a light intensity sensor which outputs a digital representation for light which strikes it.

One form of sensor is shown in greater detail in Fig. 1A wherein the bank note 10 again travels in the direction of the arrow 12. A light source 18 illuminates the surface of the bank note 10 so that light is reflected therefrom through a shield assembly 20 to a light sensor 22. The shield assembly 20 is physically arranged with respect to the light sensor 22, the light source 18 and the bank note 10 in such a manner that light reflected from a rectangular area approximately 2 mm × 80 mm on one side of the bank note 10 is detected by the light sensor 22. The analogue output of the light sensor 22 is placed on the line labelled video which, as is described in greater detail below, is stored in a storage device 24, as shown in Fig. 1.

In addition to providing an analogue output correlated to the reflected light from a rectangular area on the bank note 10, the sensor 14 includes a bank note distance-travelled sensor which will produce a pulse each time the bank note 10 travels a known distance such as 1 mm in the direction of arrow 12. One means for implementing such a sensor is to provide two rollers 26 of known dimensions which are urged toward each other to form a nip for the passage of the bank note 10, as illustrated. One of the rollers 26 is coupled to a rotation sensor including a disc with holes or slots in it through which light may pass. A photo sensor co-operates with the disc to produce an electric pulse each time the roller 26 turns through a predetermined angle. By properly selecting the dimensions of the rollers 26 as well as the slotted wheel, such an arrangement can produce a pulse every time the bank 10 travels a distance of 1 mm.

The distance-travelled pulses from the circuitry shown in Fig. 2 are utilised by the control 28 of Fig. 1 to determine when the video should be sampled to make certain that a different area is sampled than was previously sampled. For the arrangement where it is desired to determine the reflectance of light from an area 2 mm × 80 mm and the distance-travelled pulses occur once for every 1 mm of note travel, every other pulse from the rotation sensor of Fig. 1a is utilised to cause the video output to be stored in the storage 24.

The circuit of Fig. 1 additionally includes a comparator 30 for producing a signal on its output line 32 whenever the input to terminal A is greater than that at terminal B. Such comparators are well known and need not be described further.

The circuit of Fig. 1 also includes an incrementor 34 whose operation is directed by the control circuit 28 to increment a number received from the storage 24 and add one to that number and return it to storage 24. The system of Fig. 1 further includes a multiplication unit which is operative to multiply data received from the storage 24 under the direction of the control circuit 28 to produce a number which is 1.28 times greater than that input to the multiplier 32. Incrementor and multiplication units are also well known and, therefore, need not be described.

The circuit of Fig. 1 also includes an indicator 36 which is coupled to the control 28 and responds thereto to indicate the identity of the denomination of the bank note 10.

In operation, the circuitry of Fig. 1 is first operative to store a decimal representation of the output from the sensor 14 into the storage 24. This is accomplished by means of the fact that every other pulse received from the rotation sensor in Fig. 1a causes a digital representation to be stored in the storage 24. For present day United States Federal Reserve Notes, once seventy two such samples have been taken across the reverse side of the bank note 10, sufficient data is available in the storage 24 to determine the denomination of the note itself. It should be noted that the reverse side of the note, i.e. the side of a note not containing a portrait, is utilised for denomination discrimination because it contains more information relevant to the denomination of the note than does the front side.

When at least nine samples p_n (where n is an integer between 1 and 72) have been stored in the storage unit 24, the control 28 is operative in a manner shown in Fig. 2 to operate the systems to generate a plurality of multi-bit correlation numbers N. As shown in Fig. 2, n is first set to 8 and then incremented to 9. Then the digital representation for the sample p_9 is compared with the second previous sample, i.e. sample p_7. If p_9 is greater than or equal to p_7, a 1 is set in the first bit position for correlation number one. On the other hand, if p_9 is less than p_7, a zero is placed into bit position one of correlation number one. Thereafter p_9 is compared with the fourth previous sample p_5 and if the former is greater than or equal the latter, a 1 is set into the second bit position of correlation number one. On the other hand, should p_9 be less than p_5, a zero is placed into the second bit position of correlation number one.

Next the control 28 determines whether p_9 is greater than or equal to the sixth previous sample p_3. If it is, a 1 is placed into the third bit position of correlation number one and if it is

not, a zero is placed into the third bit position of correlation number one. Thereafter the control 28 determines whether p_9 is greater than or equal to the eighth previous sample p_1. If it is, a 1 is set into the fourth bit position of correlation number one and if it is not, a zero is placed into the fourth bit position of correlation number one.

Thereafter the control 28 determines whether n is equal to 72 which would be the case if all the available data had been utilised to form correlation numbers. It will be observed, however, that only sixty four correlation numbers are formed because at the outset of the sequence shown in Fig. 2, n is set to 8 so that only sixty four such correlation numbers can be generated for each bank note tested. If it is determined that n is not equal to 72, then n is incremented and a further correlation number is formed in accordance with the sequence as shown in Fig. 2. On the other hand, if n is equal to 72, all sixty four correlation numbers have been formed and the control 28 can move on to determining whether the correlation numbers are equal to previously stored correlation numbers for known denominations. The control sequence for determining the equality of correlation numbers is shown in Fig. 3.

Referring now to Fig. 3, the control 28 first causes a number N to be set to zero and subsequently incremented by one. Thereafter, the correlation number N is fetched from memory. Subsequently, the correlation numbers N_1, N_5, N_{10}, N_{20}, N_{50} and N_{100}, which correspond to the expected correlation numbers for respectively $1.00, $5.00, $10.00, $20.00, $50.00 and $100.00 notes are fetched from memory as well. Then the current correlation number N is compared with the corresponding correlation number N_1 for a $1.00 bill. If the two are equal, a $1.00 count is incremented. In either case, however, the control then jumps to a comparison of the current correlation number N with the corresponding correlation number N_5 for a $5.00 note. If correlation number N equals correlation number N_5, the $5.00 count is incremented. If not, the control jumps to a further comparison of the current correlation number N with the correlation number N_{10}. The process continues in the manner shown in Fig. 3 whereby the current correlation number N is compared with a corresponding correlation number for each particular denomination which the apparatus is capable of identifying. If the current correlation number N is equal to a corresponding correlation number N_x, the corresponding determination count is incremented.

Once the current correlation number N has been compared with all corresponding correlation numbers N_x, the control checks to determine whether N is equal to 64. If not, the process is repeated for a subsequent value of N.

On completing the sequence of events shown in the flow chart of Fig. 3, the system according to Fig. 1 has a $1.00, $5.00, $10.00, $20.00, $50.00 and $100.00 count where the count indicates the number of times that one correlation number N corresponded to a corresponding correlation number N_x for that particular denomination of bank note.

It should be noted that the above analysis assumes each note is either right side up or upside down as it passes the sensor. The system can be expanded easily to check for notes which are not always arranged the same way, i.e. the notes may be either upside down or right side up. This added feature is accomplished by comparing the current correlation number N with all corresponding correlation numbers N_x for notes right side up and with a further set of corresponding correlation numbers N_x for notes upside down. It will be recognised that this modification may also be adapted to permit the system to identify other denomination notes such as the $2.00 note.

Statistical analysis had demonstrated that when the largest count, as determined by the sequence shown in Fig. 3, is at least 1.28 times larger than the next largest count and is at least equal to 28, then the bank note corresponds to that identified by the particular denomination count which is largest. For example, if the $5.00 count is at least 28 and at least 1.28 times greater than the $1.00, $10.00, $20.00, $50.00 and $100.00 count, then the denomination of the note under test is a $5.00 note.

One sequence for determining whether a given count is at least 28 and at least 1.28 times greater than any other count for a particular bill is shown in Figs. 4a, 4b and 4c. A sequence like that shown in Fig. 4a determines which of the counts is the largest. By tracing through the decision blocks of Fig. 4a, it will become apparent that if the control exits at point A, the $1.00 count is the largest. On the other hand, exiting at points B, C, D, E and F respectively corresponds to the $5.00, $10.00, $20.00, $50.00 and $100.00 counts being the largest. A similar decision sequence is required if notes are both right side up and upside down.

Referring now to Fig. 4b, when the control determines that the $1.00 count is the largest, then a determination must be made as to whether the $1.00 count is larger than or equal to 1.28 times the next largest count. The sequence shown in Fig. 4b checks whether the $1.00 count is greater than 1.28 times all the other counts. In this manner, if the answer is yes to each check, and if the count is at least 28, it is certain that the note is a $1.00 note. The indicator is then actuated to indicate the note identity as a $1.00 note. If the $1.00 count is not at least 1.28 times all other counts, then the bill cannot be identified with sufficient accuracy and the indicator 34 is actuated to indicate that the note cannot be identified.

In a similar manner, the control as depicted in Fig. 4b is operative when the $5.00 denomination count is the largest to compare the $5.00 count with the $1.00, $10.00, $20.00, $50.00 and $100.00 count. If the $5.00 count is at least 1.28 times the $1.00, $10.00, $20.00, $50.00 and $100.00 count and is at least 28, then the note is a $5.00 note and the indicator 34 is actuated to indicate this.

The control 28 operates in a manner depicted in Fig. 4c to produce an indication that the note is a $10.00, $20.00, $50.00 or $100.00 note where the corresponding count is at least 28 and at least 1.28 times all the other denomination counts for the particular note being tested. If the largest count identified by the sequence shown in Fig. 4a is not at least 1.28 times the next largest count, or not at least 28, the note cannot be identified and the indicator 34 is actuated to indicate the same.

It will be recognised that the sequence for the control 28 as shown in Figs. 2, 3, 4a, 4b and 4c can be modified somewhat from that shown to achieve the same result with the circuitry shown in Fig. 1. In addition, it will be recognised that the discrimination of denomination in accordance with the present invention may readily be implemented by a circuit configuration different from that shown in Fig. 1 but which will achieve the same objective. For example, a system as depicted generally in Fig. 5 will operate in the manner described above to produce the same tests as that described above, although the specific details of the circuit operation are quite different. The circuit according to Fig. 5 includes at least two lamps 50 disposed in a position to illuminate a note 52 as it moves past the lamps 50 in a direction indicated by the arrow 54. The light reflected from the note 52 is sensed by a detector 56 which may comprise a type 52C solar cell manufactured by Optical Coating Laboratory Inc. of City of Industry, California, United States of America. Disposed between the lamps 50 and the detector 56 is a shield 58 with a centrally disposed opening 60 through which some light reflected from the note 52 can pass. By correct location of the detector 56, the shield 58, the note 52, and by correct selection of the size of the opening 60, the detector 56 can be made to respond only to light reflected from a given area on the note 52. As indicated earlier, the dimensions are preferably such that an area of 2 mm wide and 80 mm high is "seen" by the detector 56.

A signal conditioning circuit 62 is coupled to the detector 56 and is for amplifying the analogue signal received therefrom. After amplification, the video received from the detector 56 is transmitted by the signal conditioning circuit 62 to the edge of an engraving detector circuit 64 and to a simple and hold circuit 66. The edge of engraving detector circuit 64 produces a signal at its output 68 once it has determined that engraving on the bank note is in view of the detector 56.

The sample and hold circuit 66 is conditioned by a timing and control logic circuit 70 by way of a control signal which is transmitted to the sample and hold circuit 66 on line 72. When the signal appears at the sample and hold circuit 66 on line 72, the analogue input to the sample and hold circuit 66 becomes stored therein. The analogue signal stored in the sample and hold circuit 66 is converted by an A/D converter 76, which is coupled thereto, into digitised video data which is transmitted by way of line 78 to a peripheral inter-face circuit 80. When the micro-processor 82 is interrupted by the timing and control logic circuit 70 by an interrupt signal, the digital data in the peripheral interface circuit is transmitted to the micro-processor 82 which stores it in the random access memory (RAM) 84.

The micro-processor 82 is controlled by the control information found within the read only memory (ROM) 86. The sequence of events performed by the micro-processor 82 is generally the same as described above. On completing the scan of the note, the micro-processor 82 indicates to the peripheral interface circuit 80 the identity of the bank note in the form of a denomination indication code.

The details of the content of the read only memory 86 is shown below in Table 1 which operates in connection with the detailed circuit diagram shown in Figs. 7 to 11.

Referring briefly to Figs. 6a and 6b, the detector arrangement is shown in more detail. The detector includes a pair of parallel spaced bracket members 100 which are joined by a substantially planar member 102. Centrally located in the member 102 is a slot 104 which, as viewed in Fig. 6a, is a narrow rectangular area disposed between the plurality of lamps 106 which, in operation, are turned on in order to illuminate the note 108 as it moves by the detector.

Table 1

STMT	ADDR	CONTENT		STMT	ADDR	CONTENT		STMT	ADDR	CONTENT		STMT	ADDR	CONTENT	
1	0000	0F		46	005D	59		91	00B3	27	06	136	00FF	97	1D
2	0001	B6	07	47	005E	A6	08	92	00B5	A1	00	137	0101	D7	1E
3	0003	B7	4001	48	0060	A0	04	93	00B7	2E	F6	138	0103	DB	1C
4	0006	86	0F	49	0062	26	01	94	00B9	20	F0	139	0105	99	1B
5	0008	B7	4002	50	0064	0D		95	00BB	CE	0001	140	0107	97	1B
6	000B	86	04	51	0065	59		96	00BE	96	18	141	0109	D7	1C
7	000D	B7	4003	52	0066	A6	08	97	00C0	44		142	010B	96	1D
8	0010	8E	007F	53	0068	A0	02	98	00C1	25	01	143	010D	D6	1E
9	0013	4F		54	006A	26	01	99	00C3	08		144	010F	0C	
10	0014	CE	0001	55	006C	0D		100	00C4	9C	17	145	0110	59	
11	0017	A7	00	56	006D	59		101	00C6	26	02	146	0111	49	
12	0019	08		57	006E	A6	08	102	00C8	08		147	0112	0C	
13	001A	8C	000F	58	0070	A0	00	103	00C9	08		148	0113	59	
14	001D	26	F8	59	0072	2601		104	00CA	DF	19	149	0114	49	
15	001F	CE	83FF	60	0074	0D		105	00CC	A6	00	150	0115	97	1D
16	0022	DF	13	61	0075	59		106	00CE	08		151	0117	D7	1E
17	0024	00	1E	62	0076	53		107	00CF	08		152	0119	DB	1C
18	0027	DF	15	63	0077	DE	13	108	00D0	8C	000F	153	011B	99	1B
19	0029	DF	0F	64	0079	7F	001A	109	00D3	27	0F	154	011D	97	1B
20	002B	CE	0026	65	007C	7F	0019	110	00D5	8C	0010	155	011F	D7	1C
21	002E	DF	11	66	007F	7C	001A	111	00D8	27	0A	156	0121	96	1D
22	0030	0E		67	0082	96	1A	112	00DA	9C	17	157	0123	D6	1E
23	0031	96	16	68	0084	81	0F	113	00DC	27	F0	158	0125	CC	
24	0033	2B	04	69	0086	27	0F	114	00DE	A1	00	159	0126	59	
25	0035	81	1F	70	0088	08		115	00E0	2E	EC	160	0127	49	
26	0037	2D	F8	71	0089	E1	00	116	00E2	20	E6	161	0128	DB	1C
27	0039	86	08	72	008B	26	0A	117	00E4	DE	17	162	012A	99	1B
28	003B	B7	4002	73	008D	DF	17	118	00E6	A6	00	163	012C	97	1B
29	003E	96	16	74	008F	DE	19	119	00E8	81	14	164	012E	D7	1C
30	0040	2B	04	75	0091	6C	00	120	00EA	2D	52	165	0130	DE	17
31	0042	81	27	76	0093	DE	17	121	00EC	DE	19	166	0132	A6	00
32	0044	2D	F8	77	0095	20	E8	122	00EE	A6	00	167	0134	91	1B
33	0046	DE	11	78	0097	DF	13	123	00F0	5F		168	0136	2E	09
34	0048	9C	15	79	0099	DE	11	124	00F1	97	1B	169	0138	26	04
35	004A	27	FC	80	009B	8C	0066	125	00F3	D7	1C	170	013A	D6	1C
36	004C	08		81	009E	27	03	126	00F5	44		171	013C	27	03
37	004D	DF	11	82	00A0	7E	0048	127	00F6	56		172	013E	4F	
38	004F	DE	0F	83	00A3	0F		128	00F7	44		173	013F	20	02
39	0051	08		84	00A4	4F		129	00F8	56		174	0141	96	18
40	0052	DF	0F	85	00A5	B7	4002	130	00F9	44		175	0143	4C	
41	0054	C6	0F	86	00A8	CE	0001	131	00FA	56		176	0144	44	
42	0056	A6	08	87	00AB	DF	17	132	00FB	44		177	0145	B7	4002
43	0058	A0	06	88	00AD	A6	00	133	00FC	56		178	0148	20	FE
44	005A	26	01	89	00AF	08		134	00FD	44					
45	005C	0D		90	00B0	8C	000F	135	00FE	56					

As seen in Fig. 6a, the detector 110 is disposed on a bracket 112 which is fixed to the rear surface of the member 102. The detector 110 is positioned as viewed in Fig. 6a so as to permit light reflected from a bank note 108 to pass through the slot 104 and strike the detector 110 but light cannot hit the detector directly from the lamps 106.

As a result of the operation described above, the micro-processor 82 of Fig. 5 inputs 72 samples of digitised video data for each bank note that is scanned. Once this data is in the random access memory 84, the micro-processor 102 generates sixty four four-bit correlation numbers. The four-bit correlation number is created by taking four one-bit differences of the present sample p_n as compared with the second previous, the fourth previous, the sixth previous and the eighth previous sample. In other words, the sample p_n is compared with the second previous sample p_{n-2}, the fourth previous sample p_{n-4}, the sixth previous sample p_{n-6} and the eighth previous sample p_{n-8}. If the sample p_n is greater than or equal to the sample p_{n-2}, a binary 1 is placed into the first bit of the four bit correlation number. If p_n is greater than or equal to p_{n-4}, then a 1 is placed in a second bit of the correlation number. Where p_n is greater than or equal to p_{n-6}, a 1 is placed in the third bit position of the correlation number. Further, if p_n is greater than or equal to p_{n-8}, a binary 1 is placed into the fourth bit position of the correlation number.

Once all the four-bit correlation numbers have been generated, they are then compared with permanently stored four-bit reference correlation numbers representing the corresponding element of each denomination. If a match exists between the test correlation number and the reference correlation number, a correlation of that sample with the reference is said to exist and a correlation count for that denomination of bank note is incremented. There are a plurality of such tests performed for each sample and they correspond to one test for each denomination which can be discriminated by the apparatus when the note is right side up and a corresponding number when the note is upside down.

Once the last sample correlation number has been generated and compared with the corresponding reference correlation numbers, the micro-processor determines the denomination based on the following two criteria. If the ratio of the highest denomination count to the next highest denomination count equals or exceeds 1.28, then the denomination can only be that corresponding to the highest count. If this ratio is less than 1.28, the note is classified as being unknown. The second acceptance criterion is that the largest denomination count for the test note must equal or exceed 28. If both criteria are met, the micro-processor 82 actuates the peripheral interface 80 to produce a denomination identification code on the line so indicated.

Figs. 7 to 11 show in complete detail an implementation of a currency discriminator according to the present invention wherein all circuit types are given their parameter value or commercial designation for reader convenience and is not intended as a limitation on component value or type nor as a restriction on the scope of the invention.

CLAIMS

1. A method of identifying the denomination of a bank note or the like in which a source of light is directed onto one surface of the bank note whose denomination is to be determined, the reflectance of light from a number of incremental areas disposed along the length of the bank note is measured, the reflectance of light from each incremental area is compared with the reflectance of light from each of a pre-selected number of other incremental areas taken in a pre-selected sequence so as to produce a first correlation signal responsive to the comparison for each incremental area, and the first correlation signals are compared with respective second reference correlation signals corresponding to each denomination required to be identified so as to determine the denomination of the bank note.

2. A method of identifying the denomination of a bank note or the like, according to claim 1 in which a third signal is generated in response to the degree of correlation between the first correlation signals and the second reference correlation signals and the third signal is compared with a pre-selected standard to determine the reliability of the denomination determination of the bank note.

3. A method of identifying the denomination of a bank note or the like according to claim 2, wherein the third signal is generated in response to the degree of correlation by incrementing a denomination count when the first correlation signals correspond to the second reference correlation signals and determining and outputting, after all denomination counts have been incremented to their highest possible values for the bank note to be identified, the denomination count which is at least 28 and is at least 1.28 times larger than the next largest denomination count.

4. A method of identifying the denomination of a bank note or the like according to any one of the preceding claims wherein the comparison of the reflectance of light from each incremental area with that from each of a pre-selected number of other incremental areas taken in a pre-selected sequence and the production of the first correlation signal is carried out by producing a binary first correlation signal with a binary 1 for each comparison where the light reflected from

the incremental area is larger than or equal that reflected from a previous incremental area and with a binary 0 for each comparison where the light reflected from the incremental area is less than the light reflected from a previous incremental area.

5. A method of identifying the denomination of a bank note or the like according to claim 4, wherein the said previous incremental areas are the second, fourth, sixth and eighth previous incremental areas.

6. Apparatus for identifying the denomination of a bank note comprising means to produce a signal p_n whose magnitude is proportioned to the reflectance of light from an area of a bank note, means to store a representation for the reflectance of light from each of a plurality of different areas on the bank note, means to form a plurality of multi-bit correlation numbers N, where the first bit of each number is a one if $p_n > p_{n-2}$ but otherwise it is a zero, the second bit of each number is a one if $p_n > p_{N-4}$ but otherwise the second bit is zero, the third bit of each number is a one if $p_n > p_{n-6}$ but otherwise the third bit is zero and the fourth bit of each number is a one if $p_n > p_{n-8}$ but otherwise the fourth bit is zero, where p_n is the stored representation for the reflectance of light from a given area, p_{n-2} is the stored representation for the reflectance of light from the second previous given area, p_{n-4} is the stored representation for the reflectance from the fourth previous given area, p_{n-6} is the stored representation for the reflectance from the sixth previous given area and p_{n-8} is the stored representation for the reflectance from the eighth previous given area, means for comparing each said multi-bit correlation number n with a multi-bit number which corresponds to the same four-bit number derived from a sample note of each denomination of bank note detected by the apparatus and, on a favourable comparison, for incrementing a denomination count for the corresponding denomination, and means for producing an identity signal correlated to the identified denomination if the denomination count for such denomination is at least equal to 28 and is at least 1.28 times any other denomination count.

7. Apparatus according to claim 6 and also including means to direct light onto one side of the bank note to be identified and means to measure in sequence the reflected light from a plurality of incremental areas disposed across the side of the bank note.

8. Apparatus for identifying the denomination of a bank note or the like comprising means to direct light onto one side of the bank note to be identified, means to measure in sequence the reflected light from a plurality of incremental areas disposed across the side of the bank note, means for comparing the light reflected from each of the incremental areas with that from the second, fourth, sixth and eighth previous incremental area and producing a correlation number with a binary 1 for each comparison where the light reflected from the incremental area is larger than or equal to that reflected from a previous incremental area and with a binary 0 for each comparison where the light reflected from the incremental area is less than the light reflected from a previous incremental area, means for comparing each correlation number with a corresponding correlation number for each denomination identifiable by the apparatus, means for incrementing a denomination count when the produced correlation number corresponds to a corresponding correlation number and means for determining, after all denomination counts have been incremented to their highest possible value for the bank note to be identified, the denomination count which is at least 28 or at least 1.28 times larger than the next largest denomination count.

9. Apparatus according to claim 8 and also including means to output an indication of the denomination correlated to the denomination count that is at least 28 and at least 1.28 times larger than the next smallest denomination count.

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